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Altitude DCS Susceptibility Factors

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Introduction

Altitude decompression sickness (DCS) susceptibility factors include environmental parameters that influence the incidence and onset of DCS. These parameters include: altitude, time at altitude, exercise during exposure, level of denitrogenation (preoxygenation/prebreathe time), ascent rate, and breathing gas composition. The parameters with the most effect on DCS are altitude, time at altitude, exercise during exposure, and level of denitrogenation. These four environmental parameters are determined by mission requirements and can yield 0% to approximately 100% risk of DCS depending on interactions with the other parameters.

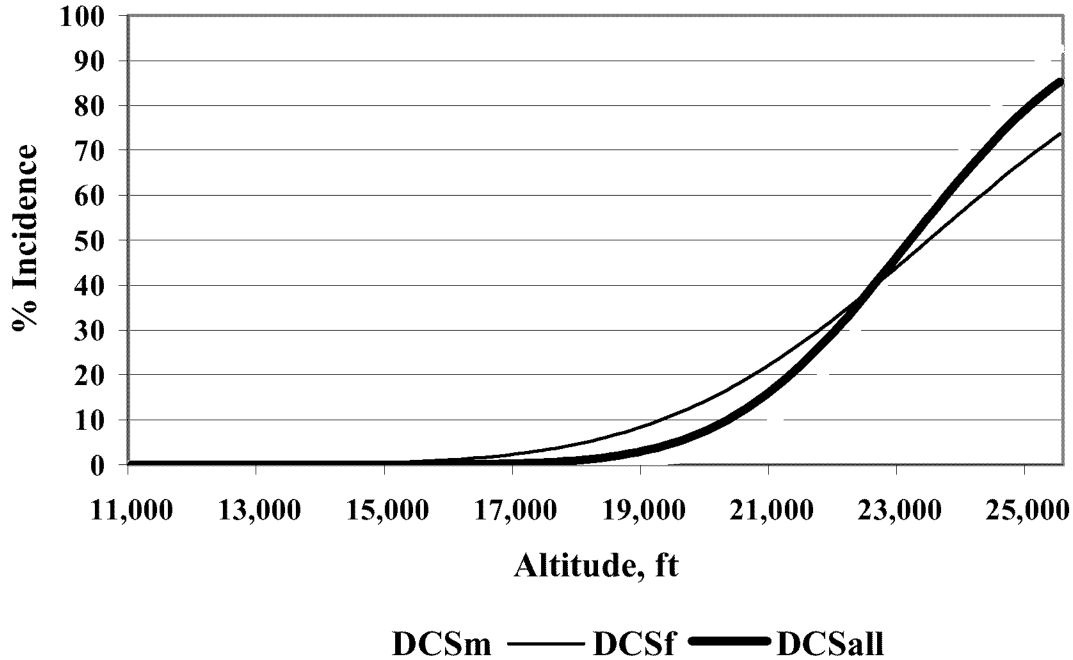

Figure 1. Altitude DCS threshold curves

The environmental factor of increasing altitude can rapidly increase the incidence of DCS symptoms (see Fig. 1; Webb and Pilmanis, 1995; Webb et al., 1998). These data came from different subjects decompressed, without prebreathe, to 9 altitudes from 11,500 ft to 25,000 ft while performing mild exercise. The 'best fit' probit curves and the individual Chi Square comparisons by altitude or as a total group of males and females did not show any differences in DCS incidence despite an apparent difference in slope of the male and female sigmoidal curves. The altitude DCS threshold curve for all subjects (DCSall) in Figure 1 shows DCS symptoms appearing below 20,000 ft and reaching 50% below 24,000 ft. The mean DCS incidence for all 182 female exposures was 47.3%, versus 51.1% DCS observed during the 360 male subject-exposures (N.S.). The effect of increasing altitude can also be shown following prebreathe. Exposures to 35,000 ft showed decreased onset times and increased symptom incidence compared to exposures at 30,000 ft and 25,000 ft despite a slightly longer prebreathe prior to the 35,000-ft exposures (Fig. 2). However, symptom severity did not increase at the highest altitude (35,000 ft), probably due to immediate recompression of subjects following any report of symptoms.

Paper presented at the RTO HFM Symposium on "Operational Medical Issues in Hypo- and Hyperbaric Conditions", held in Toronto, Canada, 16-19 October 2000, and published in RTO MP-062.

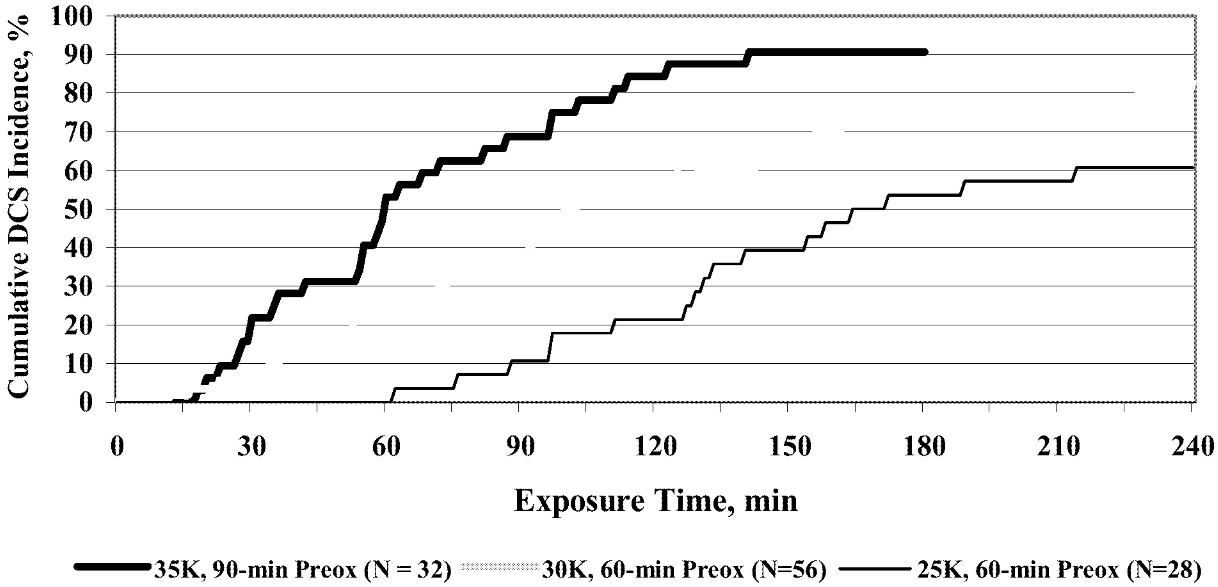

Figure 2. Cumulative DCS incidence versus time at altitudes of 25,000 to 35,000 ft; mild exercise.

Duration of exposure also increased the incidence of symptoms albeit highly dependent on altitude (Fig. 2 and Webb and Pilmanis, 1995; Webb et al., In Press). Figure 2 clearly shows that it takes longer to develop 50% DCS at a lower altitude (curve on the right) than at any of the higher altitudes where the depicted curves are displaced to the left.

The role of exercise in DCS susceptibility is also well accepted, although Pilmanis et al. (1999) reported no significant difference in DCS incidence based on whether arm or leg exercise was accomplished at altitude or whether isometric or dynamic exercise was performed (Fig. 3). Webb et al. (In Press) reported no difference between the effects of mild or strenuous exercise performed at 35,000 ft (Fig. 4). Both studies reported considerable increase in susceptibility in all comparisons of seated rest to exercise as reported throughout the literature.

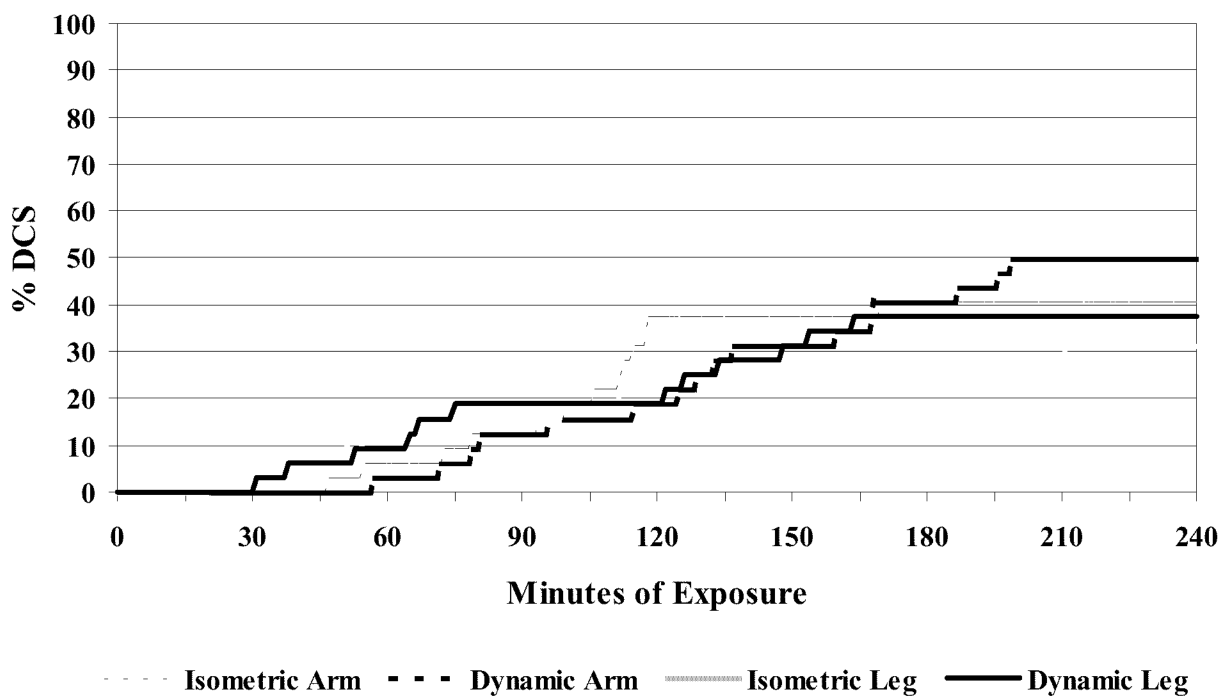

Figure 3. The effect of exercise mode on altitude DCS incidence and onset (Pilmanis et al., 1999).

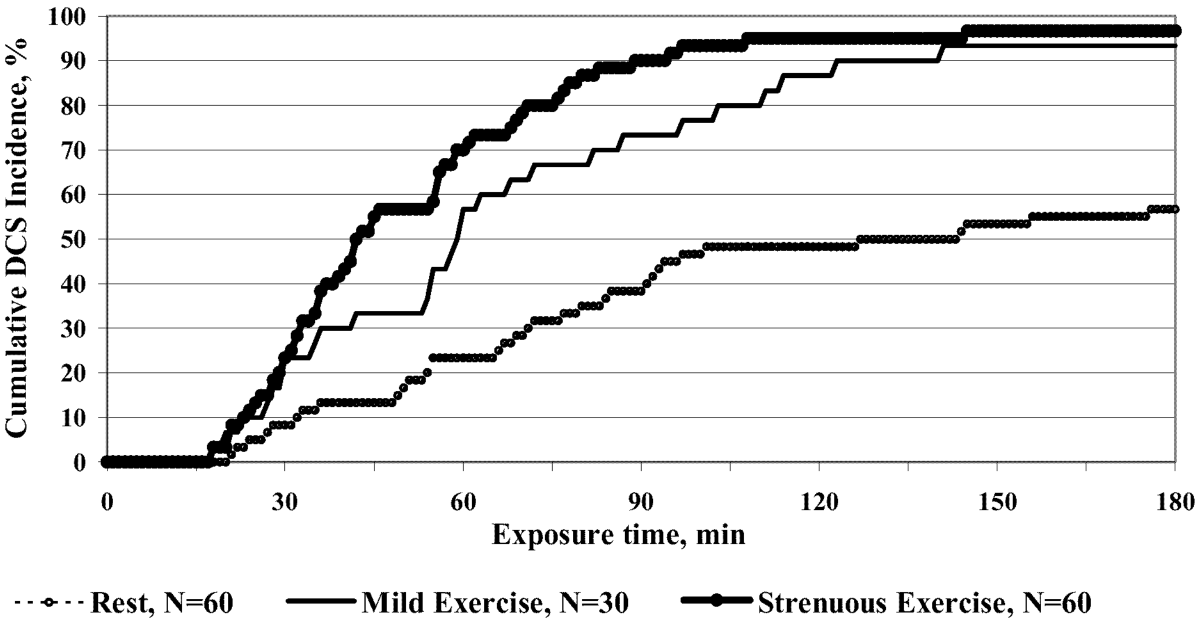

Figure 4. The effect of exercise intensity on altitude DCS incidence and onset at 35,000 ft (Webb et al., In Press).

Exercise during preoxygenation can apparently enhance denitrogenation as evidenced by significant reduction of DCS incidence compared to the incidence of symptoms following standard, resting preoxygenation (Webb et al., 1996; Paper #46, this symposium). The protective value of resting preoxygenation is better known, but its effectiveness decreases with time (Webb, et al., 1999). Predictions from the recently-developed Altitude DCS Risk Assessment Computer model (ADRAC) show decreasing efficiency of prebreathe in Figure 5. Beyond 1 h of prebreathe, only about 12% additional protection from DCS at 25,000 ft is acquired with each additional h of prebreathe.

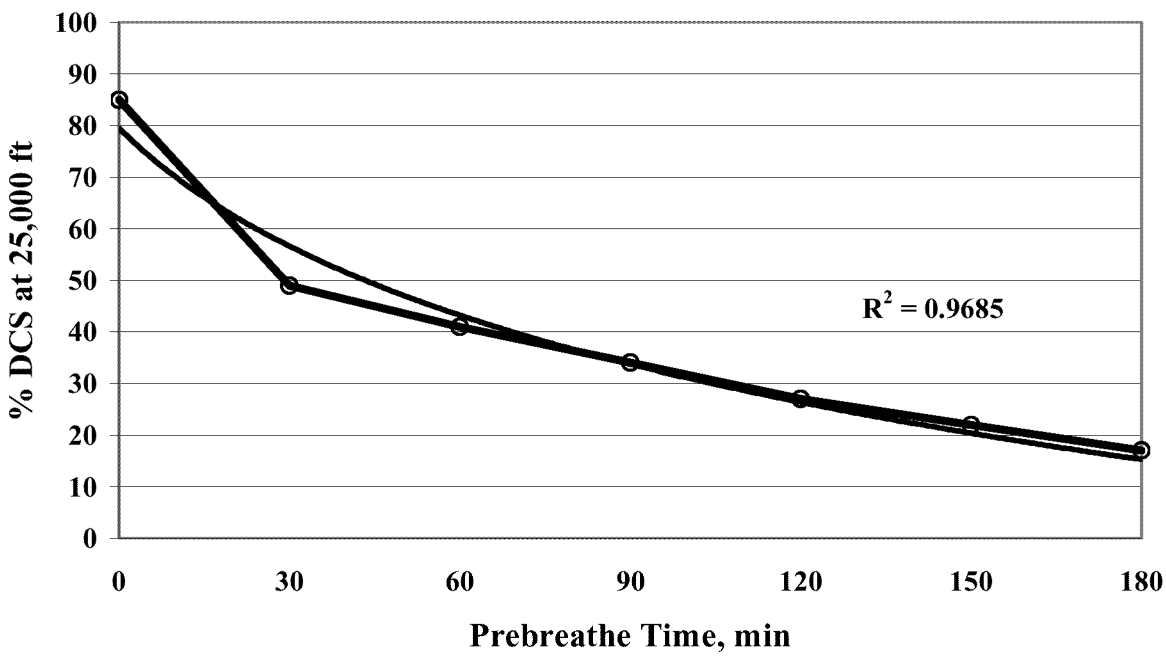

Figure 5. Resting preoxygenation time versus DCS incidence; 25,000 ft, mild exercise, ADRAC predictions

Comment

Modest alterations in environmental parameters, e.g. altitude, time at altitude, exercise at altitude, or level of denitrogenation, could significantly increase protection from DCS. Flexiblity in mission planning may be able to accommodate these alterations in the interest of avoiding DCS symptoms; i.e. flight safety.

Although the mission may involve a need for exercise while decompressed, limiting the exercise level to that needed for mission accomplishment can provide some advantage. Although we did not show that the type of exercise relates to susceptibility, the threshold exercise intensity for observing an effect on DCS incidence appears to be lower than previously believed.

Environmental susceptibility factors have provided sufficient variance to confound most attempts at risk prediction. To predict a population risk requires incorporation of at least four environmental parameters; altitude, time at altitude, exercise during exposure, and level of denitrogenation (preoxygenation time). The ADRAC model does incorporate these factors and may provide a resource for mission planning.

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